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RECOVERY OF SODA ASH FROM NAHCOLITE AND OIL SHALE

February 20, 1968

UNITED STATES DEPARTMENT OF THE INTERIOR

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OIL SHALE OFFICE
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Frank A. Peters, Paul W. Johnson
John J. Henn and David L. Boothe

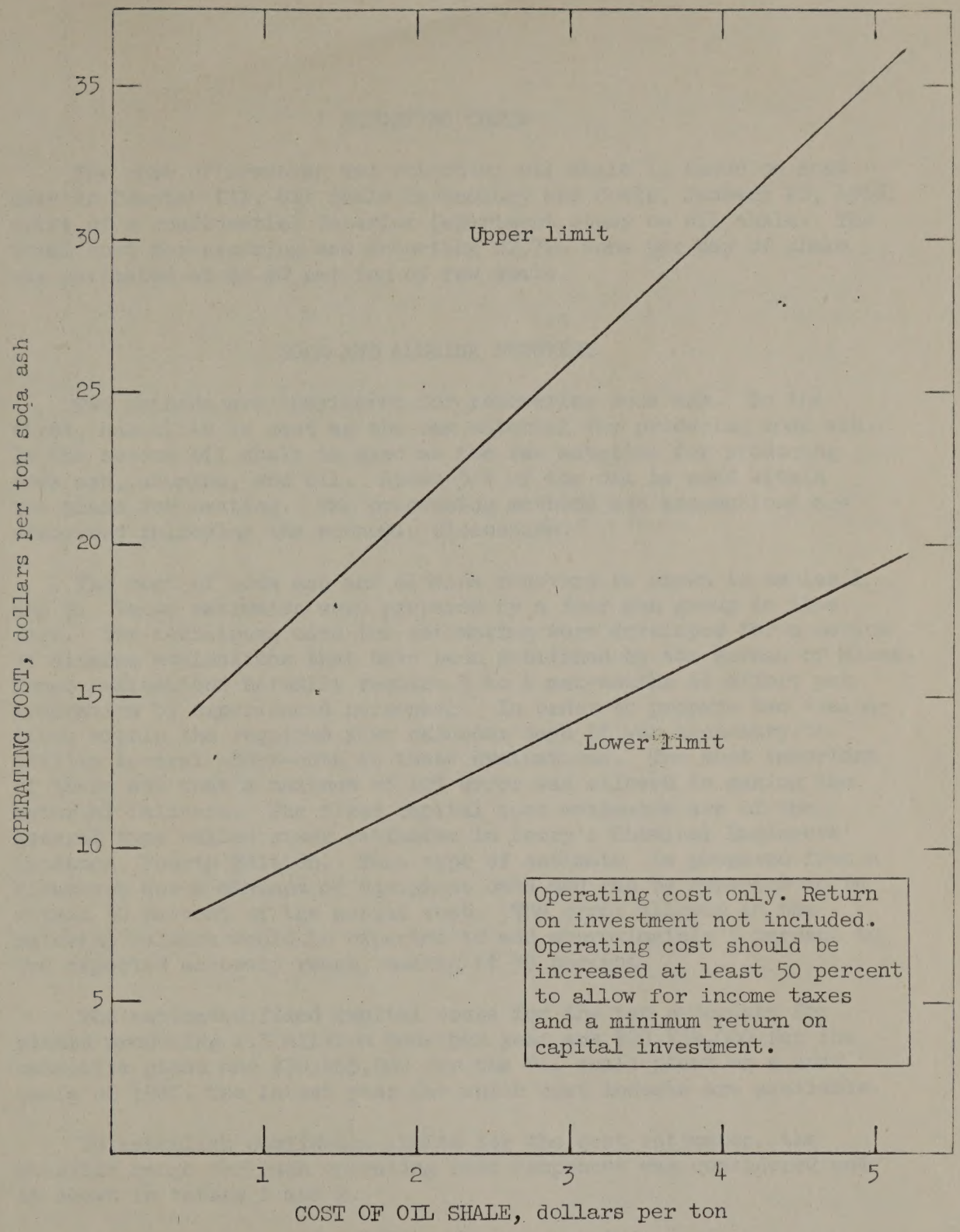


Figure 1.- Effect of Oil Shale Price on Cost of Producing Soda Ash.

RETORTING COSTS

The cost of crushing and retorting oil shale is based on cost data in Chapter III, Oil Shale Technology and Costs, January 10, 1968, draft of a confidential Interior Department study on oil shale. The total cost for crushing and retorting 22,726 tons per day of shale was estimated at $0.53 per ton of raw shale.

SODA AND ALUMINA RECOVERY

Two methods are considered for recovering soda ash. In the first, nahcolite is used as the raw material for producing soda ash. In the second oil shale is used as the raw material for producing soda ash, alumina, and oil. About 3/4 of the oil is used within the plant for heating. The processing methods and assumptions are described following the economic discussion.

The cost of soda ash and alumina recovery is shown in tables 1 and 2. These estimates were prepared by a four man group in five days. The techniques used for estimating were developed for a series of alumina evaluations that have been published by the Bureau of Mines. These evaluations normally require 3 to 4 man-months of effort per evaluation by experienced personnel. In order to prepare two evaluations within the required five calendar days it was necessary to utilize several short-cuts in these evaluations. The most important of these was that a maximum of 10% error was allowed in making the material balances. The fixed capital cost estimates are of the general type called study estimates in Perry's Chemical Engineers' Handbook, Fourth Edition. This type of estimate is prepared from a flowsheet and a minimum of equipment data and can be expected to be within 30 percent of the actual cost. The error allowed in the material balance would be expected to add approximately 5 percent to the expected accuracy range, making it 35 percent.

The estimated fixed capital costs for the two processes for plants producing 1.3 million tons per year are $29,134,000 for the nahcolite plant and $70,463,000 for the oil shale plant on a cost basis of 1967, the latest year for which cost indexes are available.

To establish confidence limits for the cost estimates, the possible range for each operating cost component was considered and is shown in tables 1 and 2.

The range for ore (nahcolite or oil shale) costs includes the estimated range for mining costs plus a 10 percent allowance for material balance errors. No additional allowance is included for variation in recovery or ore composition.

TABLE 1. - Estimated annual operating cost for producing soda ash from nahcolite.

	Lower limit	Upper limit
Direct cost:		
Raw materials:		
Nahcolite at $3.00 and $5.00 per ton	$ 8,248,000	$ 16,801,000
Chemicals for steamplant water treatment	15,000	20,000
Total	8,263,000	16,821,000
Utilities:		
Electric power at 0.6 cent per kwhr	168,000	228,000
Water, process at 10 and 60 cents per Mgal	138,000	1,013,000
Fuel oil at 25 cents per MMBtu	3,468,000	4,691,000
Coal at $2.52 per ton	48,000	66,000
Total	3,822,000	5,998,000
Direct labor:		
Labor at $3.00 per hour	657,000	803,000
Supervision, 15 percent of labor	99,000	120,000
Total	756,000	923,000
Plant maintenance:		
Labor	257,000	796,000
Supervision, 20 percent of maintenance labor	51,000	159,000
Materials	206,000	636,000
Total	514,000	1,591,000
Payroll overhead, 25 percent of payroll	266,000	470,000
Operating supplies, 20 percent of plant maintenance	103,000	318,000
Total direct cost	13,724,000	26,121,000
Indirect cost, 40 percent of direct labor and maintenance	508,000	1,006,000
Fixed cost:		
Taxes and insurance, 2 percent of total plant cost	370,000	767,000
Depreciation, 11 year life	1,722,000	3,575,000
Total operating cost	16,324,000	31,469,000
Cost per ton of soda ash	13	24

TABLE 2. - Estimated annual operating cost for producing soda ash and alumina from oil shale

	Lower limit	Upper limit
Direct cost:		
Raw materials:		
Oil shale at $1.00 and $3.00 per ton	$ 7,159,000	$26,248,000
Lime at $15.50 per ton	38,000	150,000
Chemicals for steamplant water treatment	144,000	204,000
Total	7,341,000	26,602,000
Utilities:		
Electric power at 0.6 cent per kwhr	653,000	884,000
Water, process at 10 and 60 cents per Mgal	224,000	1,643,000
Total	877,000	2,527,000
Direct labor:		
Labor at $3.00 per hour	1,000,000	1,222,000
Supervision, 15 percent of labor	150,000	183,000
Total	1,150,000	1,405,000
Plant maintenance:		
Labor	556,000	1,722,000
Supervision, 20 percent of maintenance labor	111,000	344,000
Materials	445,000	1,378,000
Total	1,112,000	3,444,000
Payroll overhead, 25 percent of payroll	454,000	878,000
Operating supplies, 20 percent of plant maintenance	222,000	689,000
Total direct cost	11,156,000	35,545,000
Indirect cost, 40 percent of direct labor and maintenance	905,000	1,940,000
Fixed cost:		
Taxes and insurance, 2 percent of total plant cost	883,000	1,834,000
Depreciation, 11 year life	4,164,000	8,648,000
Alumina and soda ash operating cost	17,108,000	47,967,000
Retorting cost:	4,240,000	4,240,000
Total plant operating cost	21,348,000	52,207,000
Credit:		
Shale oil at $1.75 per bbl	- 3,333,000	- 2,463,000
Net plant operating cost	18,015,000	49,744,000
Cost per ton of soda ash	9	26
Cost per ton of alumina	24	66

The cost range for process water is very large because other plants in the area report a large variation in water costs. In the Bureau of Mines' August 1966 preliminary report on Water Requirements and Uses in Wyoming Mineral Industries, water costs of 6 cents to 56 cents per 1,000 gallons were reported for trona processing plants.

A credit based on $1.75 per bbl from Rosar's November 7, 1967, Financial Evaluation is included in the oil shale processing operating cost for excess oil not used in the plant operation.

Because there are two products in addition to the by-product oil from oil shale processing, it is necessary to split the operating costs between the soda ash and the alumina. The basis for making this split was determined by multiplying the production quantities per year by the soda ash-and alumina-market values as obtained from the 1965 Minerals Year Book. The resulting alumina and soda ash values were used for dividing the operating costs between the two products.

The effect of sodium chloride which may be present in the shale was not considered in designing the oil shale processing plant and selecting the materials of construction. To show this effect the capital and maintenance costs have been recalculated to include the cost of corrosion resistant materials. This increases the lower limit of the operating cost to $14 per ton of soda ash and $36 per ton of alumina and the upper limit to $37 per ton of soda ash and $96 per ton alumina.

SELLING COSTS

Selling costs include all costs involved in merchandising the product (salesmen's salaries, warehousing, advertising, customer service, etc.). A cost of 2 to 4 percent of the total sales value is given in Perry's Chemical Engineers Handbook, Fourth Edition for selling bulk chemicals in carload quantities. This cost has been included in the indirect charges in the estimated operating costs.

PROCESS DESCRIPTIONS

Recovery of Soda Ash from Nahcolite

Raw material having the composition 72 percent nahcolite, 0.5 percent sodium chloride, 9.3 percent oil shale, and 18.7 percent insolubles, jointly agreed upon by the Bureau of Mines and the Geological Survey, is reduced from 2-inch to 1/8-inch material. The crushed ore is roasted at 1,200° F where the oil and other volatile matter is removed, and nahcolite is converted to sodium carbonate. The roasted product is water leached at 160° F for 15 minutes dissolving 99 percent of the sodium carbonate and sodium chloride. The insolubles are separated from the leach liquor by sedimentation

and continuous countercurrent decantation. Underflow from countercurrent decantation is discarded while the overflow is recycled to leaching. Overflow from sedimentation is clarified in polishing filters and pumped to crystallizers where 63 percent of the sodium carbonate is crystallized as sodium carbonate monohydrate. The water evaporated during crystallization is condensed and reused in the process. The slurry leaving the crystallizer is centrifuged to separate the crystals from the mother liquor. Ten percent of the mother liquor is discarded to avoid buildup of sodium chloride and the remaining mother liquor is recycled to the leaching step. The sodium carbonate monohydrate crystals are dehydrated at about 460° F to produce sodium carbonate (soda ash) with an overall recovery of 92 percent. The sequence of operations is shown in Figure 2.

Recovery of Alumina and Soda Ash from Raw Oil Shale

Raw oil shale having an analysis of 11 percent dawsonite, 24 percent nahcolite, and 27 gallons of oil per ton of shale, as determined from Geological Survey, is crushed and is retorted at 500° C to remove the oil and other volatile matter. During retorting, 28 weight percent of the oil shale is lost, as indicated in Wolf Ridge's patent application. It has been assumed that no sodium chloride or sodium sulfate is present in the raw shale.

The retorted oil shale is cooled, and is leached at about 80° F for 30 minutes with 3 tons of 0.8 molar sodium hydroxide solution per ton of retorted shale, as suggested in Wolf Ridge's patent application. After leaching the leach liquor is separated from the residue (spent shale) by settling, countercurrent washing, and filtering. The filter cake, containing 25 percent moisture as determined by the Bureau of Mines, is conveyed to a waste area.

Leach liquor from settling is clarified by polishing filters and is pumped to precipitation where 50 percent of the alumina is precipitated as alumina trihydrate. This percent precipitation is based on data from Wolf Ridge's patent application and Bureau of Mines Report of Investigations 6730. Fine alumina trihydrate is added to facilitate precipitation.

The slurry from precipitation is pumped to primary thickening to separate coarse alumina trihydrate from the solution which contains the fine alumina trihydrate. The coarse alumina trihydrate is washed, filtered, and calcined to produce α-alumina. This alumina represents a 78 percent recovery of the alumina in the retorted oil shale as given in Kaiser Aluminum and Chemical Corporation's report, "Piceance Basing Project, Current Status," of February 3, 1967. The solution containing the fine alumina trihydrate is passed through secondary and tertiary thickening to separate the fine alumina trihydrate from the soda-rich solution.

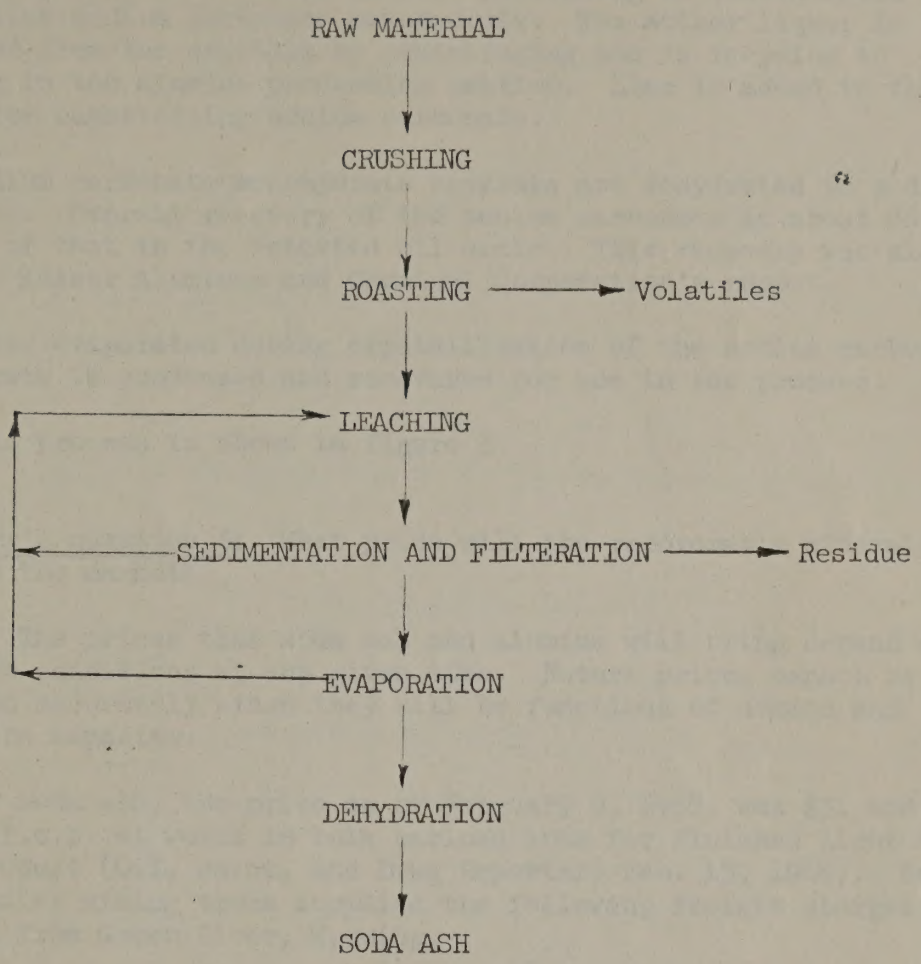


Figure 2. - Recovery of Soda Ash from Nahcolite.

Soda-rich solution from alumina processing is concentrated to crystallize sodium carbonate monohydrate. The mother liquor is separated from the crystals by centrifuging and is recycled to leaching in the alumina processing section. Lime is added to the liquor for causticizing sodium carbonate.

Sodium carbonate monohydrate crystals are dehydrated to sodium carbonate. Overall recovery of the sodium carbonate is about 86 percent of that in the retorted oil shale. This recovery was also given in Kaiser Aluminum and Chemical Corporation's report.

Water evaporated during crystallization of the sodium carbonate monohydrate is condensed and recovered for use in the process.

This process is shown in figure 3.

Solicitor's question 5: What price will the recoverable minerals bring in the market?

Answer: The prices that soda ash and alumina will bring depend entirely on market conditions at any given time. Future prices cannot be predicted accurately since they will be functions of demand and production capacity.

For soda ash, the price as of February 9, 1968, was $31 and $32 per ton f.o.b. at works in bulk carload lots for finished light and dense product (Oil, Paint, and Drug Reporter, Feb. 15, 1968). Sources in companies mining trona supplied the following freight charges for soda ash from Green River, Wyoming,

to Los Angeles	$ 8.70
to Chicago	6.30
to New York	16.77
to Atlanta	11.53

To compete with locally manufactured soda ash, the effective price of soda ash produced from trona must be lowered to absorb the freight cost. Recent contacts by Bureau of Mines field personnel with the industry in Wyoming indicate that freight charges of $14 per ton are being absorbed in order to sell on the east coast soda ash produced from trona.

The 1966 average value of natural sodium carbonates was $23.40 per ton according to the 1966 Minerals Yearbook (Vol. I-II, p. 572).

Recent U.S. production figures for soda ash both manufactured by the ammonia-soda (Solvay) process and recovered from natural sodium carbonates are

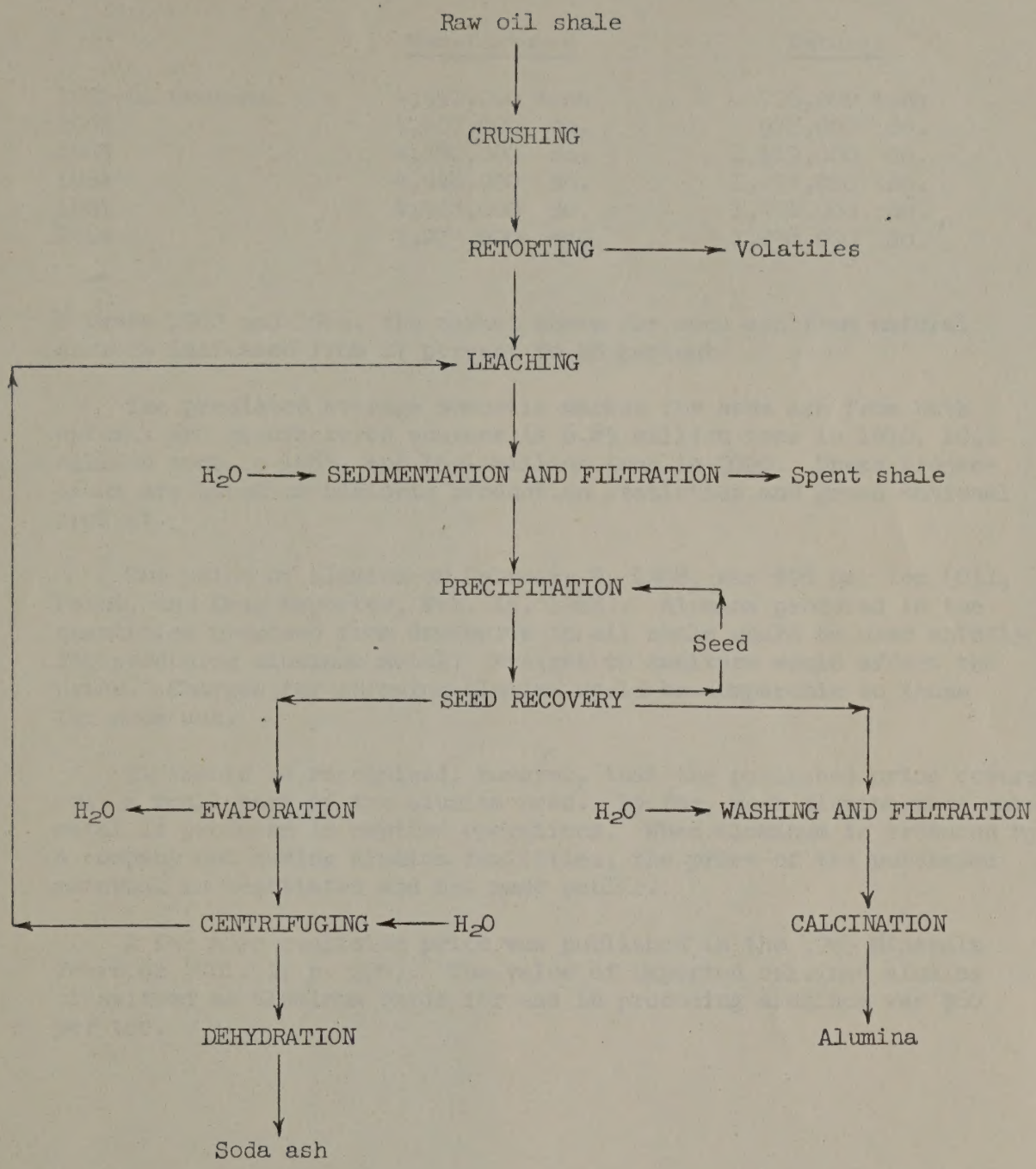
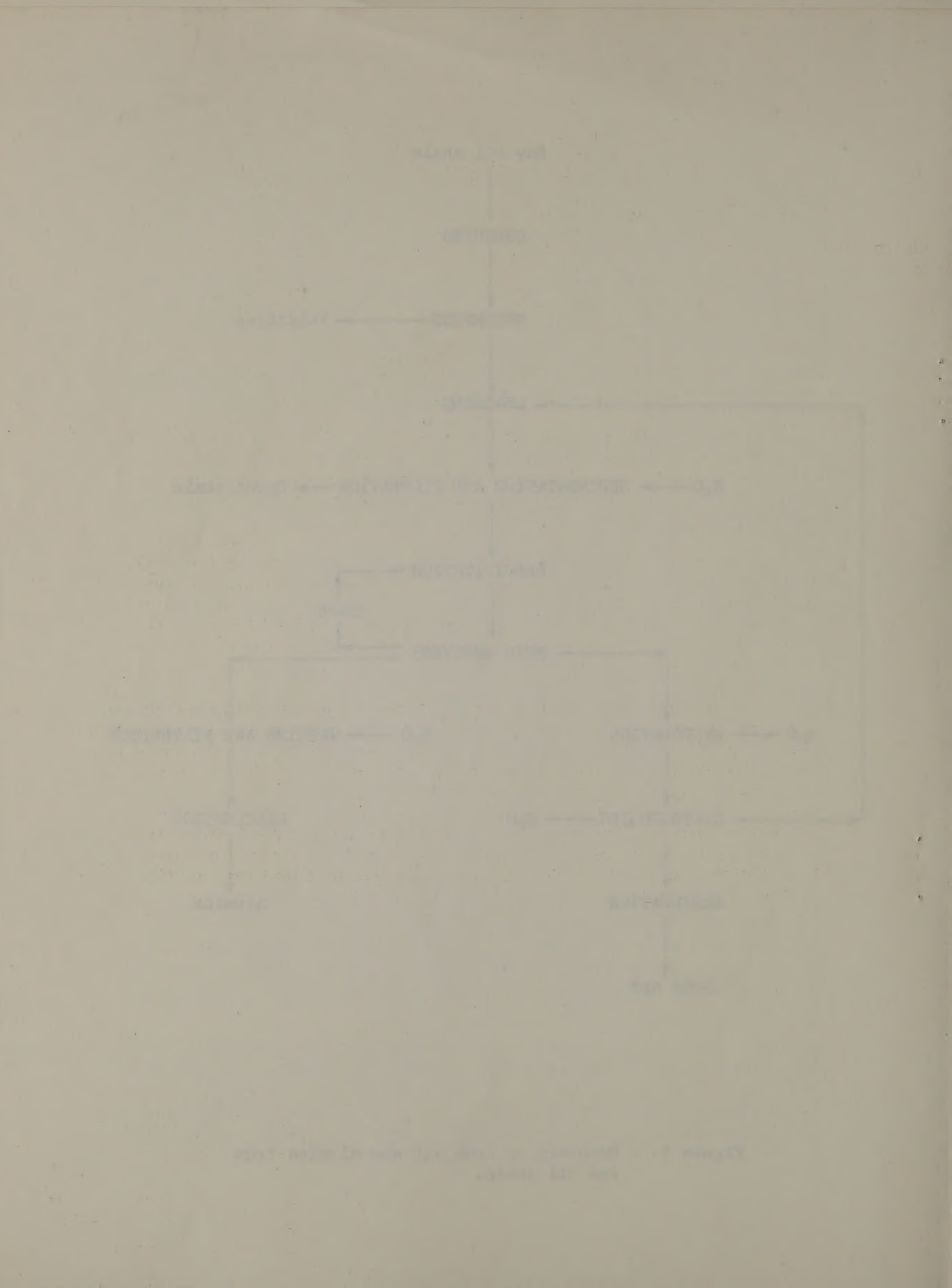


Figure 3. - Recovery of soda ash and alumina from raw oil shale.



	Manufactured	Natural
1957-61 average	4,592,000 tons	726,000 tons
1962	4,607,000 do.	978,000 do.
1963	4,682,000 do.	1,119,000 do.
1964	4,948,000 do.	1,275,000 do.
1965	4,928,000 do.	1,494,000 do.
1966	5,073,000 do.	1,738,000 do.

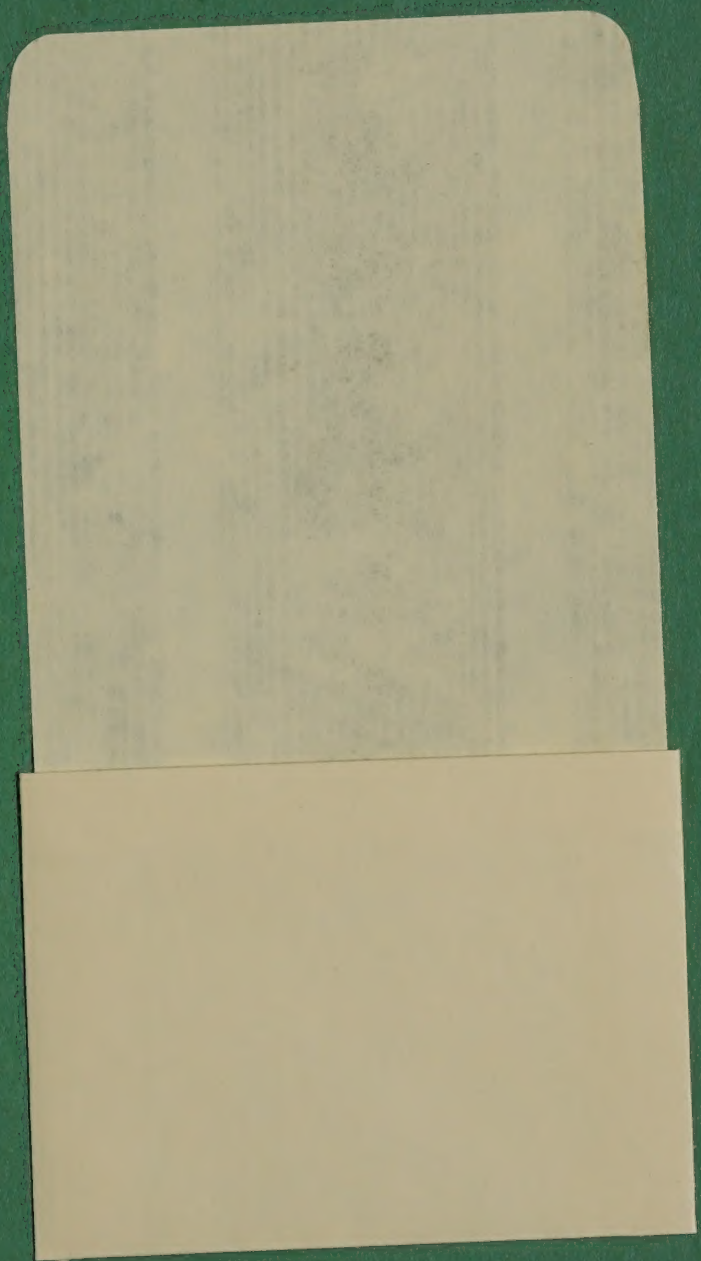
Between 1962 and 1966, the market share for soda ash from natural sources increased from 17 percent to 25 percent.

The predicted average domestic market for soda ash from both natural and manufactured sources is 6.85 million tons in 1970, 10.2 million tons in 1985, and 16.1 million tons in 2000. These projections are based on historic production statistics and gross national product.

The price of alumina on February 9, 1968, was $98 per ton (Oil, Paint, and Drug Reporter, Feb. 15, 1968). Alumina produced in the quantities proposed from dawsonite in oil shale would be used chiefly for producing aluminum metal. Freight to smelters would affect the price. Charges for shipping alumina would be comparable to those for soda ash.

It should be recognized, however, that the published price covers only a small part of the alumina used. By far, most alumina made into metal is produced in captive operations. When aluminum is produced by a company not having alumina facilities, the price of the purchased material is negotiated and not made public.

A far more realistic price was published in the 1965 Minerals Yearbook (Vol. I, p. 226). The value of imported calcined alumina classified as aluminum oxide for use in producing aluminum was $60 per ton.



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